Weatherwise

INSTRUMENTS ISSUE

Vol. 7, No. 4
AUGUST, 1954

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Instrument Congress & Exposition

The First International Instrument Congress and Exposition will be held at Philadelphia on September 13–24, 1954 in conjunction with the Ninth Annual Meeting of the Instrument Society of America. The American Meteorological Society has been invited to participate.

There will be exhibits, meetings, technical sessions, and instrument maintenance clinics. Admission to meetings and exhibits is by official badge obtained on registration. No registration fee is charged for the exhibits. For admission to the technical sessions, members of the American Meteorological Society should present evidence of membership. For others there is a registration fee of $5.00 for the technical sessions only.

The Exhibit, which will occupy 72,000 sq. ft. of the Philadelphia Commercial Museum and Convention Hall, opens at 1400 Wednesday, 15 September, and closes Tuesday, 21 September, at 1800. Hours of the Exhibit are: 15 and 20 September, 1400 to 2200. On the 16th, 17th, 18th and 21st—1000 to 1800. Closed Sunday, 19 September. The Commercial Museum and Conventional Hall is located at 34th & Spruce Sts., adjacent to the University of Pennsylvania campus.

Technical sessions on Meteorological Instrumentation will be sponsored by the American Meteorological Society and the Instrument Society of America. The program follows:

Tuesday, 21 September 1954—9:30 A.M.

The NRL Aerograph
R. E. Ruskin
Naval Research Lab.

Aerobee Rocket Grenade Instrumentation
Walsh, Stroud, Terhune, Weiland & Venner
Evans Signal Lab.

An Improved Rapid Sequence System for Atmospheric Soundings to High Altitudes
H. Demboski
Bur. of Aero.

A Fast Responding Electric Hygrometer
Wexler, Jones, Garfinkel, Krinsky, Hasegawa
Bur. of Standards

Tuesday, 21 September 1954—2:30 P.M.

An Infrared Absorption Hygrometer
R. C. Wood
U. S. Weather Bureau

The Compression Hygrometer
Brady & Brailsford
Rye, N. Y.

An Airborne Meteorological Recording System
Bellamy & Washburn
Cook Electric Co.

A Method of Instrument System Analysis
M. Smith
Cook Electric Co.

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Cover: A radiosonde flight, showing balloon, parachute, and transmitter, takes off for the stratosphere. Bendix-Friez photo.

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The Transosonde

H. D. Masterbrook
A. D. Anderson
Naval Research Laboratory
U. S. Navy

A dawn ascent of a 39-foot Transosonde balloon is prepared at Minneapolis, Minnesota. Instrumentation weighing 600 pounds will be carried aloft. U. S. Navy photo.

THE early history of aviation was marked by a colorful era of free ballooning when men ascended into the atmosphere beneath gas-filled bags to float across the countryside in the first successful conquest of the air. With the advent of power-driven aircraft, however, aviation advanced rapidly and the balloon was all but forgotten.

During World War II Japanese ingenuity was forced to develop a constant level balloon which could be automatically controlled to stay aloft for periods of several days. These balloons were successfully employed in the delivery of incendiary bombs from Japan to the North American Continent and thus, spectacularly, the free balloon returned to a significant role in the age of power flight. The pilot had been eliminated and was replaced by electro-mechanical control circuits to maintain the balloon at the desired level of flight.

The wartime achievements of the Japanese revived interest in this country in stratospheric balloon flights with the result that a program was initiated under the sponsorship of the Office of Naval Research for the development of light weight, inexpensive balloons for high altitude research. In recent months U. S. Navy polyethylene "Skyhook" balloons have carried heavy instrument loads into the upper reaches of the stratosphere to gather scientific data for a variety of research programs.

More recently the Naval Research Laboratory under the sponsorship of the Bureau of Aeronautics announced the undertaking of a project to develop the transosonde concept of weather data collection. The immediate object was the transmission of meteorological information by constant level balloons over broad expanses of ocean area where data collecting has been prohibitively expensive. The transosonde system aims to meet the meteorologist's increasing need for a complete hemispheric analysis of weather patterns as a basis for making long range forecasts.

The transosonde system consists of a balloon-borne meteorological station that can be so controlled that it will float along a standard pressure surface aloft for a period of several days. At intervals the balloon position

is determined by radio direction-finder techniques and meteorological intelligence is relayed in a coded transmission.

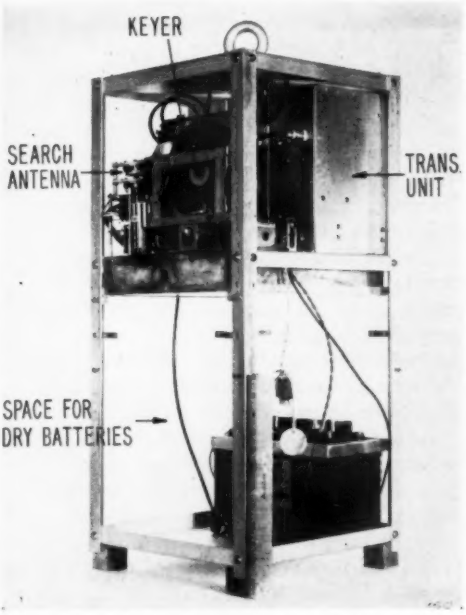
The essential components of the system are:

1. A load-carrying balloon with associated control equipment for maintaining level flight.
2. An airborne station consisting of meteorological sensing instruments, radio transmitter, and power supply.
3. A network of radio direction-finder stations for periodic position checking of the balloon and for the collection of meteorological intelligence.

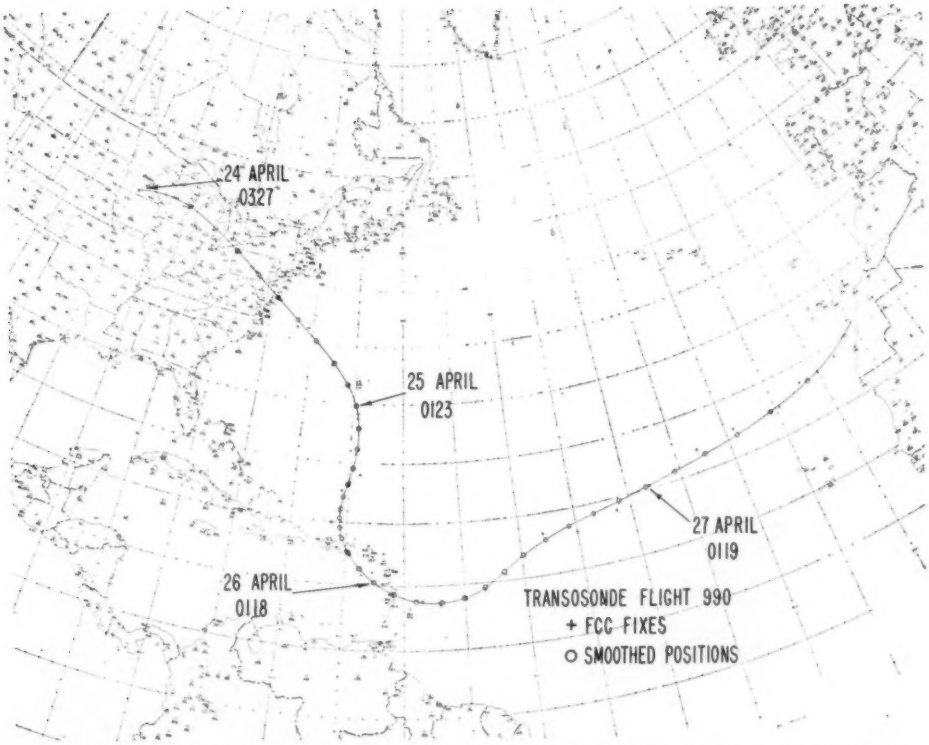
As a part of the Navy study, an experimental flight program was undertaken, using launching sites at Tillamook, Oregon, and Minneapolis, Minnesota, which resulted in an impressive series of transcontinental and trans-Atlantic balloon flights. Each flight carried a 50-watt transmitter automatically programmed to transmit once every two hours on three frequencies. Each transmission provided information as to the pressure-height of the balloons and the temperature within the transmitter pack. Balloon positions were determined during transmission periods by high frequency radio direction-finding techniques, using the appropriate facilities of the Navy and Federal Communications Commission. All flights were controlled to float along the 300 millibar pressure level at approximately 30,000 feet and were set to terminate before reaching the European or African coasts. The duration of flight to the point of termination ranged, in general, between two and four days, with the distance traveled averaging approximately 5,000 miles. These flights established the technical feasibility of the transosonde system and provided data for an assessment of the system's meteorological significance.

The primary forms of meteorological data are derived from the balloons' flight trajectories. The balloons, controlled to float along a standard pressure surface, move with the winds and thus indicate the field of motion for the selected level. The speed and direction of movement provide a direct determina-

Complete transmitter wrapped in aluminum foil is inserted in Kapok-filled bag prior to launching of Transosonde. U. S. Navy photos.



Experimental transmitter as designed by Naval Research Laboratory for transmissions on three frequencies with a power of 50 watts.



Transosonde flight No. 990, launched 24 April 1953, for flight from Minneapolis to a point off the North African coast. The course defines a trough position in the western Atlantic Ocean at the 300-mb level.

tion of the wind velocity and an indirect determination of the spacing of height contours. The passage of balloons through a trough is indicated by the shape of the flight trajectory, as illustrated for the transosonde flight of 24 April 1953. A series of flights make possible the determination of speed of movement and changes of intensity in trough configurations. The addition of temperature elements and dropsonde type units will enable sounding of temperature, humidity, and pressure through a vertical cross section to be made.

In addition to the forms of data just described, the transosonde system represents a means of collecting types of data which have not been previously available to the meteorologists—horizontal accelerations and the vertical component of motion, both important elements in the generalized equations of motion. Advantageous use of the transosonde can be made in studies of the atmospheric jet stream and high level turbulence and in atmospheric dynamics.

Navy plans call for early operational use of the transosonde system over the Atlantic Ocean and extension of operations to include the Pacific Ocean at a later date.

AMS COLUMBUS MEETING

The 131st National Meeting of the American Meteorological Society will take place on September 8–10 1954 at Columbus, Ohio. The meeting is being sponsored by the Central Ohio Meteorological Society. All sessions will meet in the Hall of Mirrors and Parlor 10 at the Deshler-Hilton Hotel. A Symposium on Atmospheric Pollution will be a feature of the meeting. Other sessions will be devoted to Meteorological Education, Climate in City Planning, Radiation and Bioclimatology.

New Air Force Weather Equipment

RUSSELL H. JOHNSON, *Supervisory Electronic Engineer, Air Weather Service*

SINCE World War II, the military services have pursued the development of new meteorological equipment with great vigor. Their object in doing so has been to improve the quality of the data which the military weather man uses in making his forecasts. The exacting requirements of the new jet age make the need for such data a matter of paramount necessity, and this, in turn, has helped to provide the impetus for the improved instrumentation now beginning to make its appearance in military weather installations. The Air Weather Service, which has been particularly forward looking in this regard, is currently placing into operation a number of newly-developed items of equipment, two of which—the Radar Set AN CPS-9 and the Transmissometer Set AN/GMQ-10—are described in this article.

RADAR SET AN/CPS-9

The Radar Set AN/CPS-9 was designed and engineered by the Raytheon Manufacturing Company, Waltham, Massachusetts, and the Signal Corps Engineering Laboratories, specifically to have the capability of searching for and locating approaching storms and precipitation areas. The 1° conical beam gives excellent target resolution and the transmitted peak power of 250 KW furnishes ample power and range. The 3.2-cm wavelength gives a more detailed structure of the target than a lower wavelength.

Figure 2 shows the grouping of the components of this radar set. The components have been divided into seven individual systems, in accordance with the individual functions of the Radar Set. A general summary of the function of each system is given below.

a. *Transmitting System.* The transmitting system includes those components which produce the transmitted pulse and deliver it to the rf system.

b. *RF System.* The rf system includes the antenna, waveguide, and duplexer.

c. *Receiving System.* The receiving system includes those circuits which accept the returning echo signals and convert them to amplified video information.

d. *Synchronizing and Indicating System.* This grouping includes those components which establish the proper time relationships between the various data applied to the indicator scopes, and the display components which present such data in their final form.

e. *Antenna Positioning System.* This system originates and amplifies the control information necessary to rotate or position the antenna in accordance with the selected mode of operation.

f. *Power System.* The power system controls the application of *ac* power to the radar and converts it to *dc* power as required.

g. *Heating and Ventilating System.* This system assists in maintaining safe operating temperatures throughout the radar.

The console, figure 1, is the "heart" of the Radar Set AN/CPS-9 in that the major controls and indicators are centralized for operation of the set and presentation of the data. From left to right in figure 1, the following indicators are shown:

a. *Range Height Indicator* whose coordinates are range and height along a particular azimuth. Standard RHI, 7-inch cathode ray tube.

b. *Range Indicator* which presents the signal strength against range along a specific azimuth. Standard A/R scope, 5-inch cathode ray tube.

c. *Azimuth and Range Indicator* whose coordinates are range and azimuth. Standard PPI, 7-inch cathode ray tube.

d. *Indicator Control* which uses a counter to indicate range.

e. *Plan Indicator* which provides an enlarged picture of a limited area of particular interest to the forecaster. Standard off-center PPI, 7-inch cathode ray tube.

In addition to the indicators located in the console cabinet, the set has a remote Azimuth and Range Indicator making it possible to

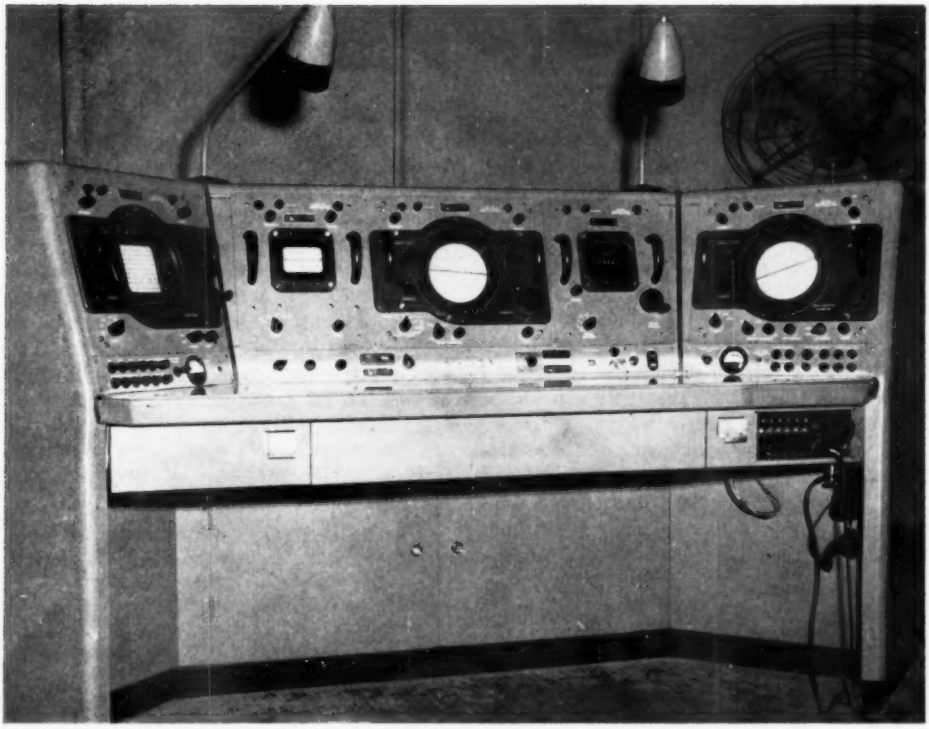


Fig. 1—The console of the Radar Set AN/CPS-9 at Maxwell Air Force Base, Alabama. Air Force photo.

present the data in locations remoted 1/2 mile from console. It is a standard PPI, 12-inch cathode ray tube housed in a console-type cabinet.

A few of the main technical characteristics are listed below:

Peak Power Output—250 KW
Operating Frequency—9,317 MC ± 87—Wavelength 3.2 cm
Range—Nominal Maximum 250 Statute Miles
Minimum 1/2 Statute Mile
Accuracy of Maximum Range—0.2%
Bearing—Choice of 360° continuous rotation, 0°–50° Sector Scan or Manual Control
Accuracy of Bearing—1°
Elevation—Choice of 0°–50° Sector Scan or Manual Control from − 5° to 90°
Accuracy of Elevation—1°
Total Weight of Set—4,060 lbs

Normal Installation Criteria—
Antenna and Antenna Control on Tower or Top of Building to clear obstructions
Modulator and Pulse Generator within 150 feet of Antenna
Console in Weather Station within 1/2 mile of Modulator

The AWS will employ the Radar Sets AN/CPS-9 initially for local weather forecasting. Studies are being conducted to develop a system for gathering synoptic information, in which the radars will be used as part of a general network to track meteorological phenomena over large areas. Some of the secondary uses of this equipment are as follows:

1. Weather information detected by the equipment and interpreted by the forecaster may be used by Flight Service Centers in controlling the movement of aircraft.

2. The data as interpreted by the forecaster will be used as an aid in pilot briefing for aircraft clearance.

The Air Weather Service is putting into operation during the next few years approximately 40 Radar Sets AN/CPS-9. These will give the meteorologist another forecasting tool to supplement the data already available, such as the synoptic map, upper air charts and adiabatic diagrams. The meteorologist will have a three-dimensional picture within a nominal 250-mile range of the Radar Set AN/CPS-9 which will give him on-the-spot information for better short-range forecasts. Much will be learned during the operational use of this equipment that will extend the horizons of applied meteorology.

In utilizing the equipment, the operator when searching for targets rotates the antenna (and hence the radar beam) through a complete 360° circle, which is known as continuous azimuth scanning. The speed of rotation is 5 revolutions per minute. The antenna position in elevation can also be varied manually while the antenna is rotating continuously in azimuth. When a storm area is detected, the operator can set the controls to sector scan in azimuth or elevation. It should be noted that azimuth and elevation sector scanning cannot be performed simultaneously. Hence, the antenna either remains fixed in azimuth and sector scans in elevation, or vice-versa.

When a storm area is detected, the *horizontal range* of a target up to 100 statute miles distant can be estimated from the horizontal target coordinate on the RHI. The *altitude* of the target between 0–50,000 feet above the horizon can be read from a graduated scale mounted in front of the RHI cathode ray tube. Figure 3 shows sketches of the displays on the four cathode ray tubes.

The *true* (*slant*) *range* can be determined accurately by viewing the Range Indicator

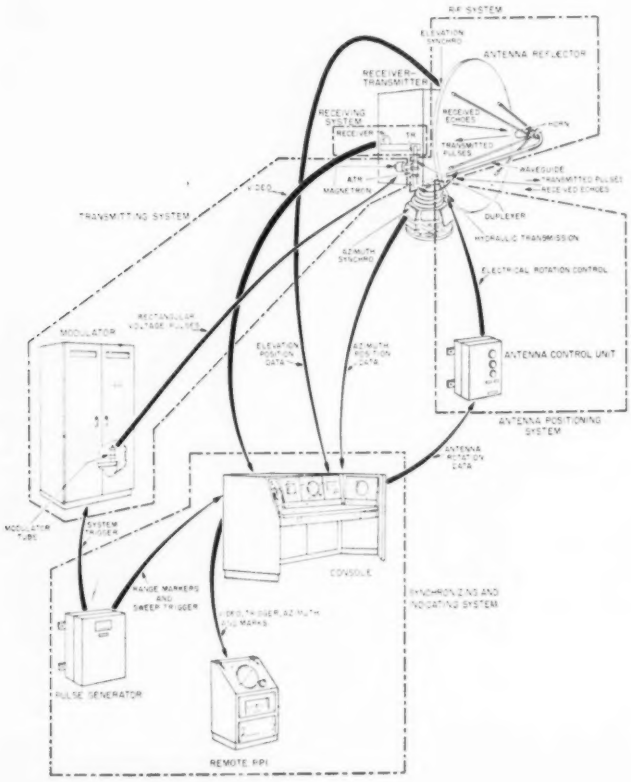


Fig. 2—A schematic diagram of the complete Radar Set AN/CPS-9.

(A R Scope). Estimate of the true range can be made by reading to the closest marker ring on the Azimuth and Range Indicator (PPI).

The *elevation* (in degrees) of a target with respect to the horizon can be read from the graduated scale around the circumference of the RHI or by reading the elevation on the graduated scale on the PPI scopes. Knowing the *slant range* and elevation both, the horizontal range and the altitude can be computed.

A direct reading of *true range* in statute miles on the Indicator Control Counter can be accomplished by manually turning the range handwheel until the adjustable range ring bisects the target on the Azimuth and Range Indicator (PPI). The range-ring position on all scopes is controlled by the range handwheel at the Indicator Control. The manipulation of the handwheel also actuates the Statute Miles Counter.

The *bearing* is selected by manually rotating a mechanical cursor (hairline) on the Azimuth and Range Indicator (PPI) until it bisects the target.

The Plan Indicator (Off-Center PPI) is used to expand the target area. This is accomplished by shifting the origin of the sweep up to two radii along the bearing cursor line. In this way, a target can be held at its original position on the scope face, but the target area can be expanded up to three times its original size for detailed study of the storm under surveillance.

So, by properly operating the controls and watching the indicators, the meteorologist can obtain first-hand information as to the actual location, coverage, and details of the structure of storm areas.

Transmissometer Set AN/GMQ-10

The transmissometer was developed in order to obtain objective measurements of horizontal visibility at strategic locations in the approach zones and landing patterns of airfields. The object was to increase the accuracy of these observations to the point that maximum operation of aircraft can be obtained under all conditions of weather. The need for such a device arose from the fact that weather observations are usually taken at locations convenient to the weather office

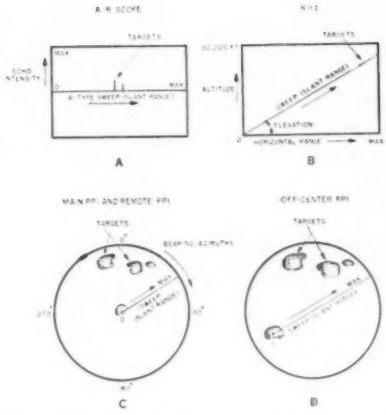


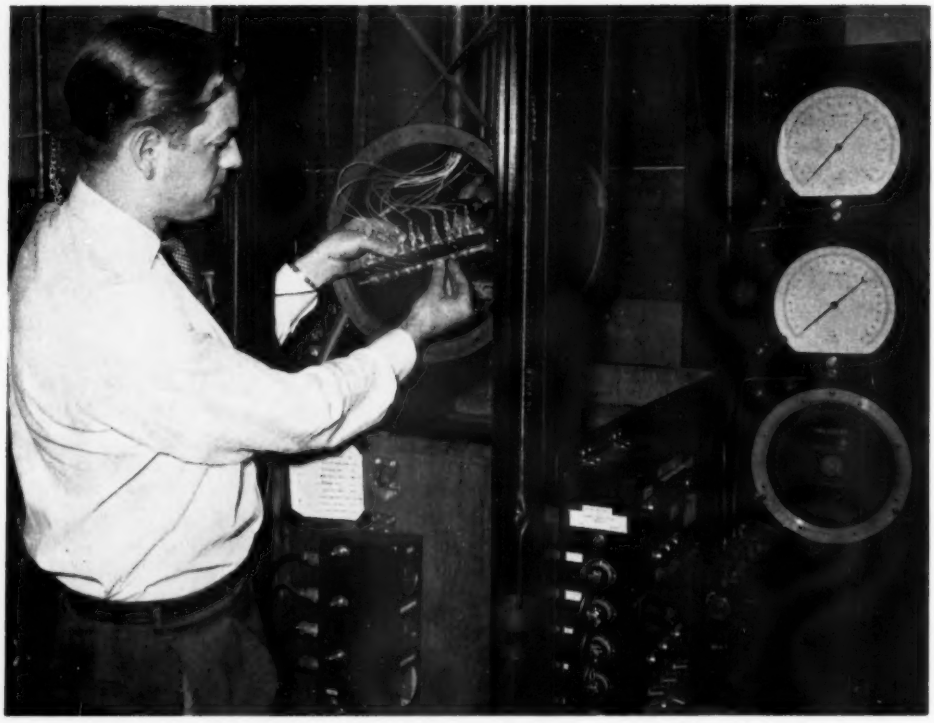
Fig. 3—Sketch of the display on the four cathode ray tubes of Radar Set AN/CPS-9.

or control tower. Unfortunately, the weather at these vantage points is frequently different from that in the touchdown or approach zones of airfields, particularly during periods of poor visibility and low ceiling. Transmissometers help to overcome this difficulty, since they make it possible to obtain measurements of visibility without stationing observers in these areas. They also provide a more sensitive measurement of changes than is possible with present periodic visual observations.

The Transmissometer Set AN/GMQ-10 was developed by the National Bureau of Standards for measuring continuously the horizontal visibility between two fixed points at a location remote from the indicator, thus making it possible to observe the visibility on the runway at the weather station. The accuracy of these visibility determinations from transmission measurements depends upon: (1) the validity of the laws used to relate transmission measurements to visibility; (2) the degree to which the density of the haze or fog in the light path between the projector and the receiver is representative of the prevailing haze or fog density; (3) the accuracy of the adjustment of the transmissometer; and (4) the accuracy with which the transmissometer readings are taken and converted to visual range values.

The relations between transmission measurements and visibility have been checked by special field tests. The constants determined

(*Continued on page 102*)



A group of new rapid-response hygrometer elements is placed in a humidity test chamber at the National Bureau of Standards for calibration. NBS photo.

Meteorological Instrumentation at the National Bureau of Standards

WILLIAM K. GAUTIER, *Technical Reports Section, NBS*

THE work of the National Bureau of Standards in meteorological instrumentation is an outgrowth of the Bureau's role as custodian of the national standards of physical measurement. In fulfilling its responsibilities in this field, NBS carries on research leading to improved standards, methods of measurement, and calibration procedures which are often of value to instrumentation in meteorology and other applied sciences. Thus, for example, work on pressure standards and humidity measurement has been applied to the development of improved barometers and hygrometers for specific purposes. Special apparatus and techniques for measuring light intensity have been utilized to devise an improved method of calibrating pyrheliometers for measurement of solar radiation. Many such projects have been undertaken at the request of the Weather Bureau, the Navy, and other Government agencies.

The radiosonde—now used daily by the Weather Bureau at many stations—was originally developed by NBS in 1936. Carried aloft by a small balloon, this device employs an ultra-high-frequency oscillator and a modulator to telemeter data on upper air pressure, temperature, and humidity as the balloon ascends to a height of 80,000 feet or more. Over a period of years, the Bureau has continued to carry on performance evaluation studies of radiosondes for the Navy Bureau

of Aeronautics. This work, dealing with both the electronic transmitter and the measuring elements, has made possible useful improvements in the quality and measurement accuracy of present day radiosondes.

For evaluation of hygrometer elements, special equipment has been developed which produces and maintains atmospheres of known relative humidity at any of the temperatures encountered in a radiosonde flight, particularly the low temperatures of the upper air. In this apparatus, a known relative humidity is produced by saturating a stream of air with water at a given temperature and then raising the temperature of the air to a specified higher value. In effect, the equipment serves as a working standard of humidity, drawing requests from other Government laboratories for the evaluation of hygrometers at low temperatures. Development of high-precision apparatus for measuring relative humidity by a microwave method is now under way.

As a result of the pressing need for more accurate humidity data of the upper air, the Bureau has designed and constructed improved electric hygrometer elements of high sensitivity and extremely rapid response for use in radiosondes. This work is sponsored by the Aerology Section of the Bureau of Aeronautics. At the rate of balloon ascent now employed in radiosonde flights, 1,000 feet per minute, and the greater rates that are contemplated, slow response in the humidity element introduces an uncertainty in the interpretation of the data. It is expected that the more rapid response of the Bureau's improved hygrometer will make possible increased accuracy and reliability in aerological measurements. Like some previous hygrometers, the device depends on the change in electrical resistance of a salt film with the change in the humidity of the surrounding air.

In preliminary experiments at the Bureau it was found that the response limitations of the lithium chloride hygrometer currently in use are principally due to the relatively long time required for the water vapor in the air to diffuse into or out of the plastic binder and to thereby change the concentration of the lithium chloride solution. An effort was therefore made to develop an electric hygrometer which would depend on the physical adsorption of water vapor on a film surface rather than the slower process of absorption within the film layer. Experiments with various types of materials eventually led to a rapid-response hygrometer consisting of an extremely thin film of a salt, such as potassium dihydrogen phosphate, evaporated under vacuum on a specially treated flat strip of glass or other insulating material. Water vapor is rapidly adsorbed on the surface of the film and reaches its equilibrium concentration very quickly. An electronic circuit measures the resistance of the film, providing a continuous record of humidity.

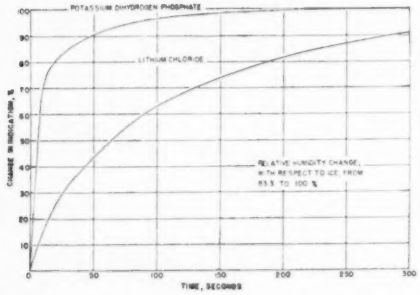
Thus far, experimental studies of the rapid-response instrument have been concerned primarily with the size and material of the insulating blanks, the treatment of the uncoated blanks, the configuration and spacing of the electrodes, the thickness of the deposited salt film, and the chemical nature of the salt. Two base materials have been studied: glass and polystyrene sheet. To remove any free alkali which might possibly contaminate the salt film, the glass has usually been treated by washing with detergent and water, rinsing in benzol, and leaching in nitric acid at 80° C for one hour. The polystyrene is treated by

A potassium dihydrogen phosphate hygrometer element, developed by the NBS, is placed in a standard radiosonde. NBS photo.

washing with soap and water and rinsing in benzol.

With this hygrometer, a 63-per cent change in indication, caused by a sudden change in relative humidity, takes place in less than 1/2 second at room temperature and in about 10 seconds at − 20° C. In comparison with the standard hygrometer element in current use, this represents a 24-fold increase in speed of response at room temperature and a 13-fold increase at − 20° C.

Investigation of the performance characteristics of the Bureau's hygrometer is continuing. The effects of such factors as temperature, polarization, exposure to high humidity, and aging are being determined. Other materials are also being investigated to determine their suitability as hygrometer elements.


POTASSIUM DIHYDROGEN PHOSPHATE
LITHIUM CHLORIDE
RELATIVE HUMIDITY CHANGE, WITH RESPECT TO ICE, FROM 65.5 TO 100 %
CHANGE IN INDICATION, %
TIME, SECONDS

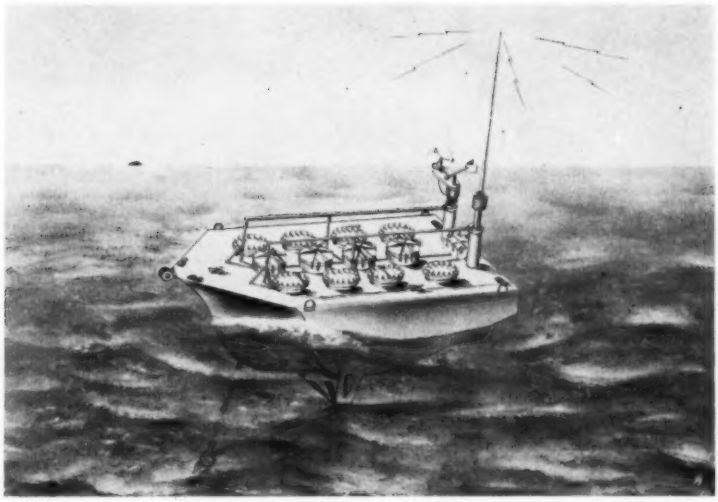
A graph showing the comparative speed of response of the new potassium dihydrogen phosphate humidity element with the currently used lithium chloride element.

The Bureau has also done work on the aerological balloons which carry radiosondes aloft. Until recently actual flight tests of sample balloons were necessary in order to determine the expected performance of a group of balloons in service. The customary rubber tests used in the laboratory were not adequate for this purpose as they do not measure the properties of rubber under a two-dimensional stretch at low temperature. At the request of the Bureau of Aeronautics, NBS has worked out a method of test which simulates conditions in flight. This test, in combination with measurements of ozone resistance and neck strength, should provide the necessary information for evaluation of aerological balloons in the laboratory.

Another program is concerned with means of providing accurate weather data needed to insure safe landings at airports. During periods of restricted visibility, measurements taken at a weather station, sometimes as much as two miles from the runway, do not always give a true picture of the runway conditions. For accurate measurements of the ceiling along the active runways, NBS developed the ceilometer for the Weather Bureau several years ago. The transmissometer, an instrument for measurement of visibility in landing areas, was developed more recently by NBS under the sponsorship of the Civil Aeronautics Administration, the Bureau of Aeronautics, and the Air Force. During tests remote-recording equipment installed on these instruments provides a continuous record of the ceiling and visibility conditions of fogs in critical locations. Further work in this field, sponsored by the Bureau of Aeronautics and the Weather Bureau, seeks to improve both the guidance given the aircraft pilot and methods of forecasting the visual guidance to be expected at the time of landing.

During World War II, NBS developed two types of automatic weather stations for the Bureau of Ships. One of these, named the "Grasshopper," can be parachuted from aircraft into inaccessible territory, where it automatically sets itself up and periodically transmits weather observations by radio. The other device is a free-floating buoy-type weather station which operates in similar fashion. An improved form of "wiresonde" was also devised for the Bureau of Ships, providing increased accuracy in the measurement of atmospheric temperature and humidity gradients at altitudes up to 2,000 feet.

In addition to the development of instruments and devices, NBS calibrates various types of meteorological instruments—anemometers, thermometers, pyrheliometers, aneroid and mercurial barometers—for the Weather Bureau and other Government agencies. NBS also assists the Weather Bureau and the Navy in the development and selection of wind-measuring systems for field use. A current project is concerned with the development of enclosures for weather instruments that will permit more accurate measurement and recording of temperature and humidity under all weather conditions than is possible with the wooden shelters now in use.



An artist's sketch of a Navy boat-type automatic weather station transmitting weather data from a remote ocean area.

The Navy's Automatic Weather Stations

ELBERT F. CORWIN AND F. W. VAN STRATEN, *Naval Aerological Service, U. S. Navy*

IT is relatively easy to get weather reports from populated areas. Weather, unfortunately, is hemispheric in scope. To forecast successfully, it is necessary to know what is going on in the atmosphere at all places, even though some of them are uninhabited, inaccessible, or just watery areas in the Atlantic or Pacific oceans.

To meet the problem of getting weather reports where there are no human observers to record what is going on in the atmosphere, automatic weather stations have been developed.

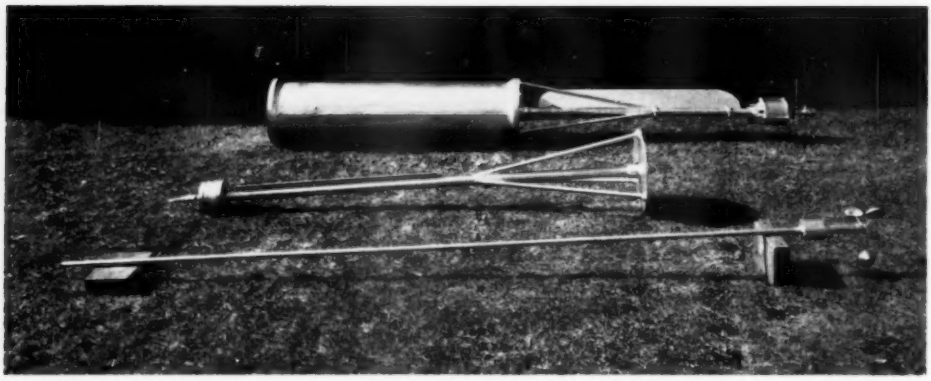
The Navy's first successful automatic weather station was a large, shore-based station, the so-called Navy TDM-1, which could be erected on islands and along coastal areas. Several of these were located in the South Pacific and in the Aleutians during World War II, completing a network of weather observations needed for naval surface and air operations.

BOAT-TYPE AUTOMATIC WEATHER STATION

Since World War II, the Navy has concentrated on other types of automatic weather stations. Out of this effort, three different types have evolved. The first is a boat station developed for the Navy at the National Bureau of Standards by Percival D. Lowell and William Hakkarinen. The 20-foot aluminum hull can be anchored in water as deep as 600 fathoms. With its 12-foot beam width, it is designed to ride out any storm. Twelve wells in the boat contain the ballast, the power packs, and the instrumentation necessary for the functioning of the automatic weather station. Above deck, the anemometer, the wind vane, and the antenna protrude together with a flashing navigation beacon.

A boat station of this type can transmit weather information by means of coded radio signals for a period of three months. The signals have a range of from 700 to 1,000 miles.

Both air temperature and sea-water temperature are measured as well as atmospheric pressure, wind speed, and wind direction. A timing mechanism can be pre-set to put the station on the air according to any fixed time schedule. The automatic weather station starts its transmission by first giving its call letters in Morse code. The next series of dots and dashes indicates the atmospheric



The components of a floating-buoy automatic weather station with tail pipe and antenna removed to show greater detail. NBS photo.

pressure. The three-letter code group can be translated by a radio operator on a ship or shore station, perhaps 500 miles away, in terms of the number of millibars of pressure exerted by the atmosphere at the boat's location. Other code groups give him the information necessary to assign numerical values for the temperatures, wind speed, and wind direction observed by the boat.

At the present time, the primary electrical power supply consists of two hundred dry cell batteries. There are plans for developing a sea-water battery in order to increase the operating life of the station.

Extensive field tests will determine its performance, maximum and optimum operating range, battery life, and signal readability. The initial tests will be made with the boat anchored in Chesapeake Bay. Deep water tests in 600 fathoms of water will be made during 1955.

Free-Floating Buoy

The second type of automatic weather station under development by the Navy was started during the latter part of World War II. It is a free-floating automatic weather station which can be used in water of any depth. While this is often an advantage over the anchored boat, free-floating introduces a much more rigorous requirement for operational reliability. Transmissions must be such that the position of the free-floating automatic weather station is always known. It must not become a hazard to navigation.

Instead of using a boat-type hull, this station is constructed as a buoy, 27 feet in overall length. It weighs approximately 280 pounds as against the 15,000 pound weight of the boat station. The buoy cylinder is five feet long and 16.5 inches in diameter. An eight-foot tail pipe ending in 40 pounds of lead ballast is fastened to the bottom of the cylinder. On top is a seven-foot structure bearing the anemometer and a seven-foot antenna.

Meteorological information is transmitted in a predetermined sequence at intervals of three hours. The same five meteorological variables—air temperature, water temperature, atmospheric pressure, wind speed, and wind direction—are transmitted by the buoy as by the boat. No weather vane is used to determine the wind direction. Instead, the buoy as a whole serves as a highly damped weather vane. Once it is oriented in the direction of the wind by an air-rudder device, the direction is reported by a modified aircraft magnetic compass inside the buoy.

Range and unattended life are not as great for the buoy as for the boat. The battery pack provides power for 30 days unattended operation. The radio range is limited to approximately 400 miles.

The original model was designed by the National Bureau of Standards. The present equipment, undergoing preliminary tests in the waters around the Washington area, was developed by the Naval Electronics Laboratory. Further tests during the coming year will include, along with determination of its meteorological reliability, the consistency of

accurate pinpointing of the free-floating buoy by direction finder stations.

The Parachute Weather Station

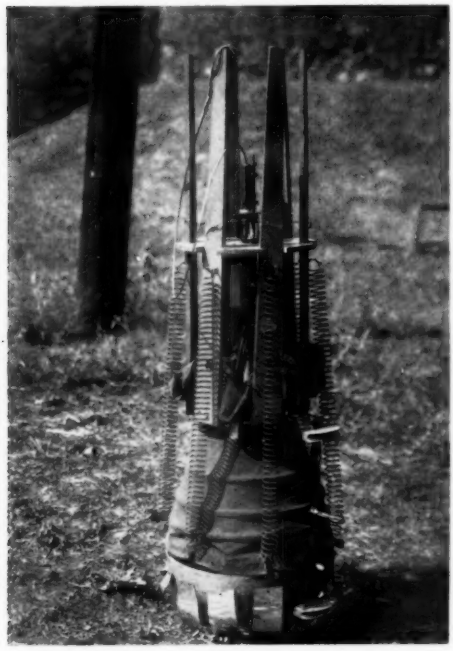
But probably one of the most remarkable automatic weather stations, with the emphasis on *automatic*, is the parachute automatic weather station. Once launched from an aircraft by parachute, it goes ahead quite on its own.

It is a bomb-shaped aluminum alloy structure containing a parachute, self-erecting mechanism, telescopic antenna, crystal-controlled transmitter, battery power supply, meteorological instruments coding mechanism, and associated components.

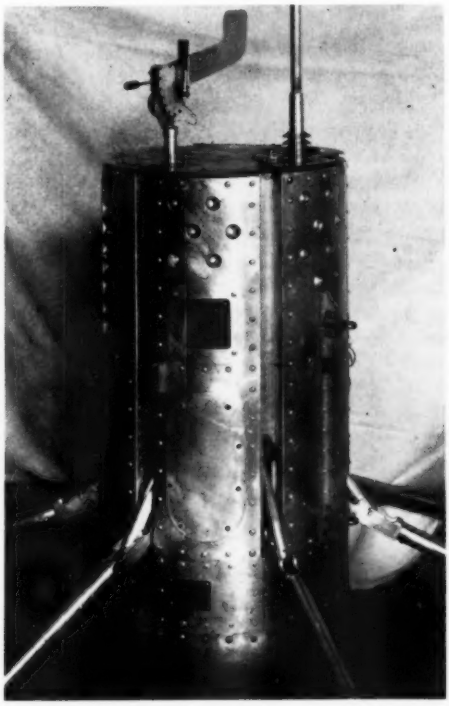
The weather station may be carried by aircraft on standard internal or external bomb racks and dropped by a 30-foot, extended skirt-type parachute at the desired operating site. The parachute is detached on ground contact by means of an automatic release assembly. Erection of the weather station is accomplished after a predetermined time interval by a pneumatic system. An inert gas under a pressure of approximately 1,200 pounds per square inch forces six legs outward and downward, locking them in the position shown in the illustration.

After erection of the station the telescopic antenna is extended by the gas under pressure. Again, five meteorological variables are measured and transmitted in code form.

The weight of the complete weather station including parachute is approximately 175 pounds. Completely assembled and ready to load on an aircraft, the station is 80 inches in length and 18.5 inches in diameter with four tail-cone fins increasing the diameter approximately eight inches. The power supply for the station consists of a 12-volt lead acid battery. At moderate temperatures the ampere-hour capacity of the battery is sufficient to provide weather information every six hours for a period of three weeks.



The interior of a parachute automatic weather station. Station has landed, but the leg-release device has not yet functioned to raise the station into a transmitting position. NBS photo.



An experimental model of a parachute automatic weather station. Legs are extended and parachute has been removed. U. S. Navy photo.

Highlights of United Air Lines Weather Radar Evaluation

HENRY T. HARRISON, *United Air Lines*

EARLY in 1953 a weather mapping radar was installed in an United Air Lines DC-3 Cargoliner, soon nicknamed and fondly referred to as "SIR ECHO." The Douglas Aircraft Corporation made the nose radome installation and United's San Francisco maintenance base completed the installation. The radar was a Radio Corporation of America product and operated on the C-band of 5.5 centimeters.

Radar controls and a set of flight instruments were located at the radar operator's position in the left forward corner of the cabin. A radar camera and periscope were installed on the radar observer's scope to permit simultaneous viewing and picture taking. A second scope was installed in the cockpit between the two pilots and was equipped with a three-eyepiece viewer. NACA and Ryan gust recorders, which record airspeed, vertical acceleration, altitude, time, and radar picture times, completed the installation.

Standard 5-inch airborne-type Plan Position Indicator scopes (PPI displays) were used. On this type display the aircraft is considered as being located at the center of the scope, as shown in the accompanying photo, with the antenna beam cutting an essentially horizontal $7\frac{1}{2}^\circ$ wedge-shaped slice out of the storms it sweeps through.

The antenna installation in Sir Echo permitted echoes to be seen only in the area 125°

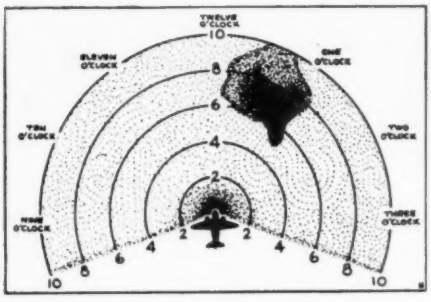


Fig. 3—The scope presentation.

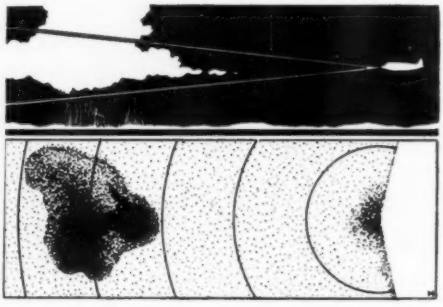


Fig. 4—Radar beam cutting slice through storm cloud and the resulting scope presentation.

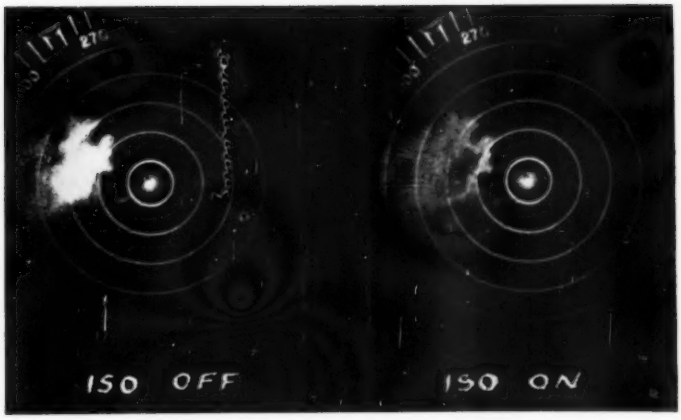


Fig. 5—Precipitation echoes.

either side of straight ahead. The concentric circles are range marks spaced two miles apart. Radar echoes move from the top of the scope toward the bottom while the aircraft is maintaining a constant heading. The RCA radar had three ranges: a 10-mile range with 2-mile marks, a 30-mile range with 5-mile marks, and a 100-mile range with 25-mile marks.

A sample single cloud echo is shown in the left portion of figure 5; the 10-mile range is being used and the cloud echo exhibits the typical fuzzy-edged and rounded characteristics of a precipitation echo. Range marks of 360° appear in this and subsequent scope photographs because our antenna rotated continuously through a full circle. They were not shown in figures 3 and 4 in order to emphasize that the DC-3 installation did not see targets in the four (4:00) to eight o'clock (8:00) sector.

To give the pilot more information about the structure of a storm, our radar was equipped with Isoecho Contour Circuitry as an aid in locating the areas of most rapid change in precipitation rate. The ISO ON portion of figure 5 shows what happens to a simple precipitation echo when iso-circuitry is turned ON. For all practical purposes this circuitry displays two rates of precipitation: the lighter rate defined by the outer edge of the echo and the heavier rate by the outer edge of the black ISO hole.

A typical rugged terrain radar scope picture using the 30-mile range and 5-mile range marks is shown in figure 6. The sharp edges on these echoes, the dark shadows, and the concentric arc characteristic are typical of all rugged terrain echoes. Figure 7 shows a

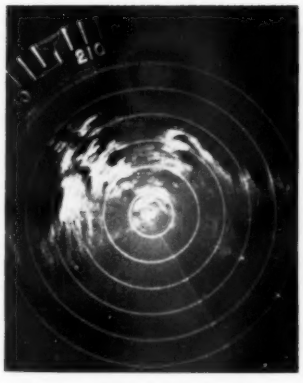


Fig. 6—Rugged terrain echoes.

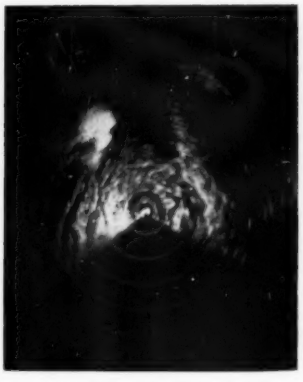


Fig. 7—Cloud and terrain echoes.

Fig. 8—Flight through storm area.

cloud echo at 20 miles at 11:00 in the midst of terrain and is a good example to show the sector scanned by the radar antenna.

Unlike previous thunderstorm probing research by the Thunderstorm Project, American Airlines, and the Navy, where pilots went out of their way to find trouble by flying through the cores of thunderstorms, Sir Echo and his crew started out in June 1953 to prove that thunderstorm conditions could be flown without getting into trouble—"trouble" in this case meaning heavy turbulence, damaging hail, and tornadoes. We knew from previous experience and research that the hard cores of thunderstorms were to be avoided and that heavy turbulence is usually associated with areas of most rapid change in precipitation rate, so paths were picked which would avoid the hard cores as shown in figure 8.

Evaluation flights were conducted out of Denver beginning 1 June 1953, and in the next four months 40 technical and operational flights were made, totaling 133 hours of flying, 80 of which were in the immediate vicinity of or through corridors of thunderstorms. Denver turned out to be a most desirable base of operations, permitting a sampling of all types of thunderstorms except the hurricane and true nocturnal. Associated with these thunderstorms were a more than normal amount of hail, five cases of known tornadoes, and four cases of cloudburst or near cloudburst rain.

Captain George Henderson, who flew Sir Echo during the evaluation program, has done an excellent job of highlighting the most important evaluation conclusions in his answer to the question, "What exactly can the pilot do with radar that he has not been able to do before?"

(1) He can detour a *storm* area after having scanned it from over 75 or more miles away (fig. 9), thus giving him the opportunity to instigate a detour at a point where his flight time will be increased very little.

(2) He can *choose* a corridor of the mildest activity or turbulence if penetration of a storm area is desirable or necessary (fig. 10). Normally, a suitable corridor can be found without departing more than 5 miles from the planned flight path.

(3) He can scan the *area* around an airport before taking off or landing, to determine the best possible flight path out of or into that airport (fig. 11).

(4) He can *establish* his position relative to high terrain or easily distinguishable ground features (fig. 12).

(5) He can give valuable *information* to other aircraft not equipped with radar, thus reducing operational delays during storm seasons (fig. 13).

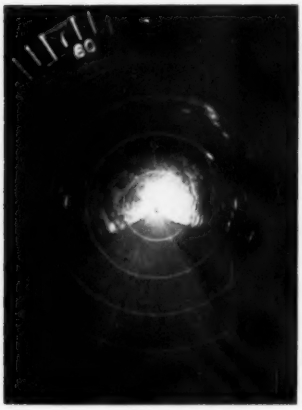


Fig. 9—Group of storms at 50 and 75 miles (25-mile range marks).

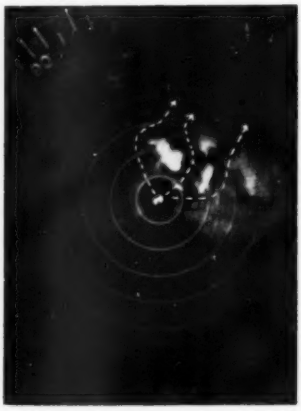


Fig. 10—Selecting corridors between storm cores (5-mile range marks).

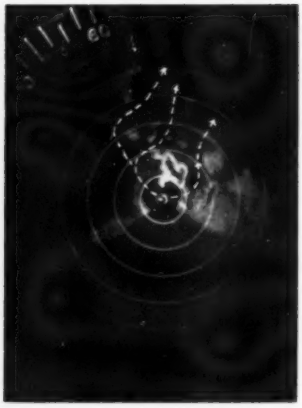


Fig. 11—Possible routes through storms (5-mile range marks).

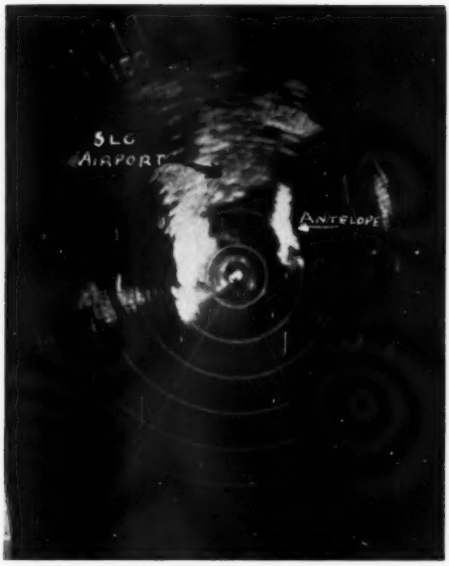


Fig. 12—Salt Lake Valley looking from south (5-mile range marks).

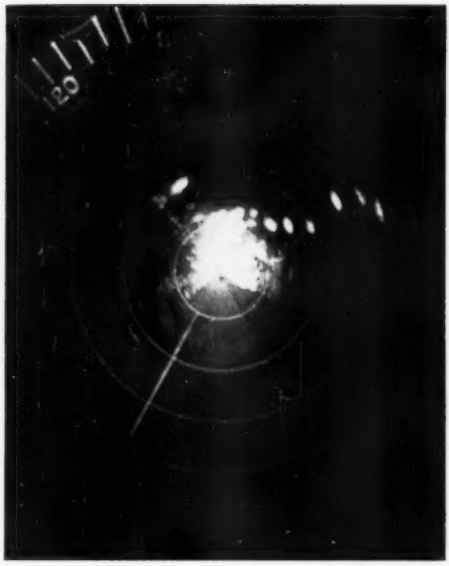


Fig. 13—Line of storms with wide gaps (25-mile range marks).

Airborne radar, in doing these five things, will permit the pilot to avoid damaging hail and provide the passengers with a relatively smooth ride through thunderstorm conditions. Furthermore, considerable indirect evidence is provided by the radar scope which will permit a pilot to avoid tornadoes by exercising ordinary good judgment in detouring sharp-edged echoes and finger-like projections from such echoes. Airborne radar, we are sorry to report, has very little, if any, application in avoidance of other aircraft.

METEOROLOGICAL INSTRUMENTS

W. E. Knowles Middleton & A. F. Spilhaus

The new and extensively revised edition of this well-known professional textbook includes descriptions of the newer devices which have come into use in upper atmosphere sounding, electronic techniques for wind plotting, thunderstorm location, etc., and takes into account the renewed interest in meteorological observations from aircraft. 256 pages. Photographs and drawings. $11.50

TECHNIQUES OF OBSERVING the WEATHER

Benarthur C. Haynes

A practical book that tells the amateur how to observe and record weather data. The author treats means and methods of observation thoroughly and gives detailed instructions on the uses of instruments, charts and forms. Illustrations of professional and amateur instruments included. A final chapter describes an improvised weather station for amateurs. 272 pages. $4.50

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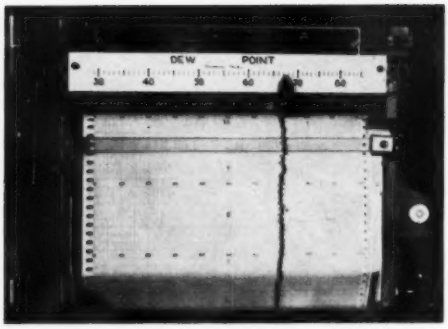


Weather Bureau

Improvements in Meteorological Instrumentation

WILLIAM R. THICKSTUN, *Chief, Instrument Division, USWB*

THE trend in meteorological instrument development is in the direction of remote indicating and automatic means of making measurements of atmospheric conditions. This concept extends from the employment of radar for storm detection to the sensing of the various atmospheric elements and placing the information automatically on a teletypewriter circuit. These improvements are twofold: they extend the horizon of the observer and make available for other purposes the time now consumed in going out-of-doors to take an observation. Outstanding developments in this program of the Instrument Division of the U. S. Weather Bureau are the adaptation of airborne radar for meteorological purposes, an automatic observer, the development of a new method for determining the water vapor content of the atmosphere, and a quick response, rotating-beam ceilometer. The last two of these will be discussed in detail.

A few months ago the Weather Bureau announced the development of a new and superior method for determining the amount of water vapor present in the atmosphere, utilizing a new instrument which is called an "infrared absorption hygrometer." Its response is practically instantaneous without changing in the slightest degree the property of the air being sampled.

This new instrument utilizes a beam of light containing two separate wave lengths which pass through the air being sampled. One of the wave lengths, 1.37 microns, is absorbed by water vapor, while the other, 1.24 microns, passes through the air undiminished. The ratio of energy transmitted in the two wave lengths can be used as a direct index of the quantity of water vapor present in the light path.

The most interesting and sensational feature of the equipment is its ability to measure moisture at extremely low temperatures and low concentrations of water vapor where practically all field systems for measuring moisture completely break down. As a matter of fact, the accuracy of this infrared system for measuring moisture increases as the concentration of water vapor becomes less. It is expected that this system will be of immeasurable assistance to many types of research organizations in addition to its use by the meteorologists.

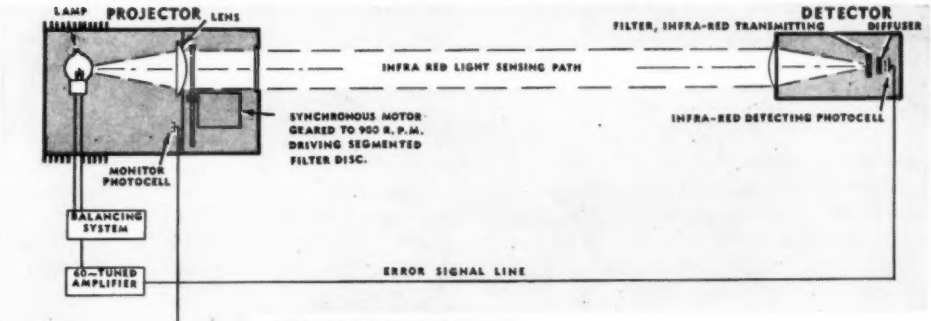
The absorption spectra instrument has several advantages not found in other hygrometers. First, as to the method of sampling, it is possible to sample instantaneously any desired path length of atmosphere from a few inches to thousands of feet, and in so doing arrive at an integrated value of the absolute humidity in the path in question. If the path

is appreciable, the value obtained is more representative than that obtained by spot sampling. Second, the method has an advantage over others because of the nature of the absorption function. Surprisingly enough, the absorption function results in an increase of sensitivity of the measuring equipment as the humidity concentration decreases. In contrast, the psychrometer, hair hygrometer, electrical hygrometer, and even the dew point apparatus all become less sensitive or more difficult to operate as the air temperature falls and the humidity becomes less. Since no change of state is involved in the absorption method, the equipment will operate as well below the freezing point as above it. Third, the speed of response is limited only by the speed of the indicator or recorder. This makes the method ideal for use in measuring humidity from an airplane or under any circumstances where rapid changes in humidity can occur. Finally, the method in no way alters the sample concentration by either adding or subtracting water or changing the state of any part of the sample as occurs in psychrometer and dew point methods.

The principle of this system has been well known for a number of years; in fact, an article by two Weather Bureau employees entitled "A Spectroscopic Hygrometer" appeared in the Bulletin of the AMS, April 1943. However, it was not until recently that two essential devices required for the development of a practical instrument became available. These devices are the transmission type interference narrow band-pass light filter and the photoconductive lead sulfide cell.

The transmission type narrow band-pass light filter consists of two highly reflecting, but partially transmitting, films of silver separated by a transparent spacer film deposited on a glass surface and protected by a cover glass. The separation of the silver films determines the wave length position of the band-pass. Where the optical separation of the silver films is effectively a half wave length or a multiple of half wave lengths, there is high transmission, but light of other wave lengths is reflected rather than transmitted. Filters of this type have been available commercially for several years, but it

How The Infrared Hygrometer Operates.



DESCRIPTION OF COMPONENTS:

AMPLIFIER Hi Gain Amplifier L-C Tuned to 60 ~. (Three 12AU7's)

BALANCING SYSTEM A Phase Sensitive Circuit Employing a Brown Servomotor to Drive a 100 Watt Gen. Radio Variac.

DIFFUSER Glass, with Flat Transmission Characteristics between 1.25 & 1.37 Microns.

FILTER, INFRARED TRANSMITTING Corning #7-56 2mm

FILTER, ROTATING DISC. Bausch and Lomb Special Interference Filter 4 1/2" Dia., 8 Segments with Pass Bands Alternately Located at 1.25 & 1.37 Microns.

LAMP Westinghouse 108 W, 6 V Projection Type (Special).

LENS 3" Dia. 8" Fl. Plano-Convex. Libby Owens "Color Clear" Glass (Special).

MONITOR PHOTOCELL Weston, "Photronic" 856 RR Temp. Compensated and Herm. Sealed

PHOTOCELL, DETECTING Eastman Kodak Lead Sulfide "Ektron Detector" with Resistance Matching Input of Amplifier.

RECORDER Brown, Self Balancing Potentiometer, 3-6 MV Var. Range.

MOTOR Bodine KYC 26 1800 RPM, Synchronous.

MISC. NOTES Components Sealed in Dry Atmosphere with Phosphorous Pentoxide. Detecting Photocell Kept at Constant 120°f with Heater & Precision Thermostat. Detector Lens also Heated. Details not Shown.

The projector and detector of the infrared hygrometer, front view. USWB photo.

The projector and detector of the infrared hygrometer, rear view. USWB photo.

has been only recently that they have become available with pass-bands out in the infrared where the deep water vapor absorption bands are located. These infrared filters simplify the design of absorption spectral equipment since through their use an entire spectrophotometer can be replaced by an appropriate pair of light filters and a simple collimating system.

The photoconductive lead sulfide cell was developed in Germany and in the United States during World War II. This cell is sensitive out in the infrared region to about 3.5 microns. It is sensitive in the area between 1 and 2 microns, where many water vapor bands are located, and its sensitivity is many times greater than a good laboratory bolometer. This photoconductive cell, because of its extreme sensitivity, fast response (in the order of 200 microseconds), and its dark impedance (0.1 to 2.0 megohms) is ideal for use in conjunction with an a-c electronic amplifier which is required to operate an indicator or recorder.

This device is regarded as a decided improvement in equipment for the measurement of atmospheric water vapor and the illustration shows the first operational model of this equipment at the Weather Bureau in Washington, D. C. A modified version of this device is being built for use on an airplane. A simplified form, it is hoped, will make it economically possible to provide every important weather station with a sensitive and reliable moisture measuring device for the first time in history.

Foreseeing the need for a more accurate method of determining cloud heights at airports, the Weather Bureau in 1939 began work with the National Bureau of Standards to use a photo-electric means to measure the height of clouds which could be used at night as well as day. As a result of this work the basic principles of the "ceilometer," now in general use by the Weather Bureau and the Armed Forces, were developed.

Since the minimum ceiling height under which transport type aircraft are now landed is usually between 300 feet and 500 feet (depending on airport conditions, type of aircraft, and other factors), there has developed a pressing requirement for frequent, accurate observations of the cloud height in the landing area. The conventional ceilometer was

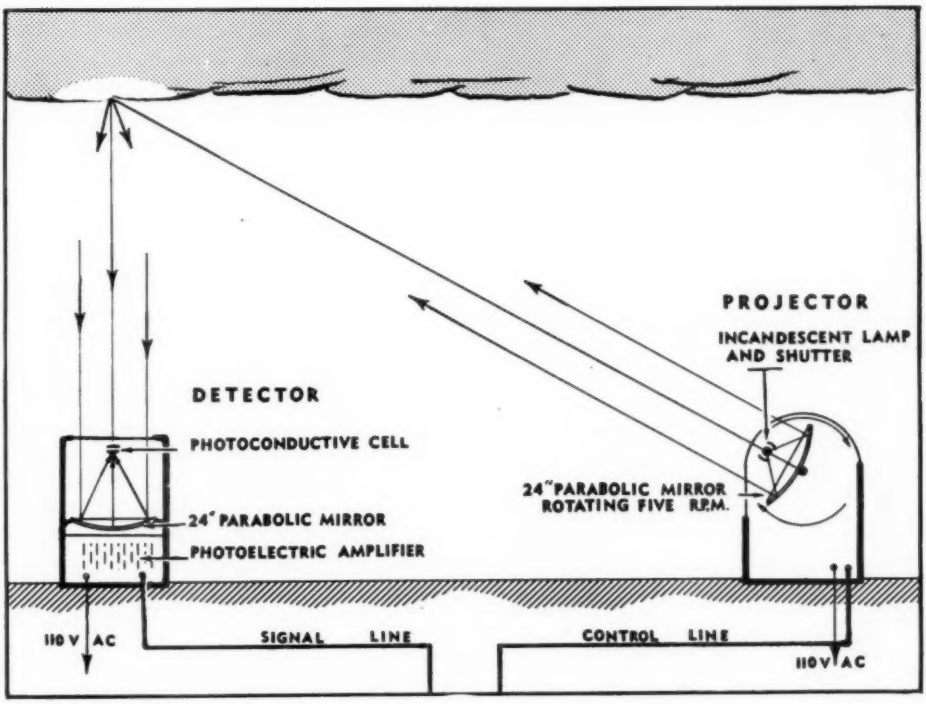
not able to meet these stringent requirements, and the Weather Bureau's Instrument Division was therefore put to work on developing a new type of ceilometer. From this work has evolved what is now known as the "rotating-beam" ceilometer.

The rotating-beam ceilometer system works on the triangulation principle and consists of three major components: a projector, a detector, and an indicator. The beam of light from the projector is rotated continuously in a vertical plane and is modulated in order to make the light identifiable to the detector, through whose field of view the light beam passes. The field of view of the detector is toward the zenith. As the beam of light from the rotating projector intersects the base of the cloud, a part of the reflected light is received by the detector. In turn, the detector transmits a signal to the indicator. The indicator, being synchronized with the rotation of the projector, translates the received signal into an indication of the actual height of the cloud. A sketch showing these principles is shown.

The projector contains a 240-watt high current incandescent lamp mounted so that its filament is at the focal point of a 24-inch parabolic mirror. The mirror and lamp are contained in a drum supported on horizontal trunnions and a synchronous motor rotates the drum at the rate of five revolutions per minute. A motor driven barrel-type shutter is mounted in the drum in such a manner that the light collected at the mirror is interrupted at a rate of 120 times per second. This modulates the flux of the projector beam and makes it possible for the detector to discriminate between the beam of light from the projector and other light sources.

The detector consists of a lead sulfide photo-conductive cell mounted at the focal point of a 24-inch parabolic mirror. The output of this cell is fed into a high-gain audio amplifier tuned to a frequency of 120 cycles per second, and having a band width of about

How The Rotating-beam Ceilometer Operates.



The Detector.

The Projector.

The Indicator.

90 cycles. Because the sensitivity of the photocell falls off rapidly at high light flux levels, an infrared filter is placed between the mirror and the cell. This filter and the spectral response of the cell combine to make the detector sensitive to the spectral region between 1 and 2.5 microns, a region in which the incandescent lamp is rich in radiation. Newer equipment will differ from the present units in that the projector will have two beams of light 180 degrees apart, thus giving a cloud measurement each six seconds instead of the present 12 seconds.

The indicator consists of a cathode ray tube, a synchronous motor and associated electronic circuits. The design is such that the spot on the cathode ray tube makes four vertical traverses across the tube diameter for each revolution of the projector drum. All vertical sweeps of the cathode ray tube are blanked out except the one in synchronization with the height measuring sweep of the projector. A signal from the detector is indicated by a horizontal deflection of the cathode ray tube spot that is proportional to the strength of the signal received. Cloud heights are indicated by noting the point on the scale on the tube face where the horizontal deflection occurs.

This system of transmitting the angular position of the projector beam to the indicator eliminates multiple circuits which would otherwise be required. Hence, with power at the projector and detector sites, the only wiring required is a 2-wire telephone line between the indicator and the detector and a similar control line between the indicator and projector. This arrangement permits placing the projector and detector many miles from the weather observatory or control tower without the use of expensive multiple conductor cables. Moreover, this system permits the use of simple VHF radio equipment as a connecting link between the components of the system. The radio link feature is very useful in cases where the placement of the equipment is such that connecting cables must be laid underground to stay clear of runways and taxiways.

Physiographic Maps and Globes

Semi-contour maps and globes are a distinctive type of teaching aid, useful in demonstrating concepts in meteorology, climatology, and geography. The international scheme of color contouring is employed to show elevation. The contrasting colors of these maps and globes make the elevation pattern of the area immediately apparent. Only geographically important information is shown, with emphasis on major features of slope, drainage, and elevation. Up-to-date 1950 census figures are employed.

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(Other mountings available)

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Philadelphia 8, Pa.

Air Force (*Continued from page 85*)

from these tests are used as a basis for the conversion tables used with the set. The tables and curves were designed to give conservative values of visibility.

Usage has shown that during periods of restricted visibility the measurements obtained from a transmissometer located in the approach or touchdown zones of an airfield are more representative of conditions there than are visibility measurements made at a weather station some distance away. On the other hand, when the atmosphere is relatively clear, local smoke, haze, or dust in the vicinity of the transmissometer may cause considerable differences between the visibilities indicated by the instrument and those obtained visually.

The following definitions are furnished for the purposes of clarifying the terms used:

TRANSMISSIQN. The ratio of the transmitted to the incident light as measured.

LIMIT OF VISIBILITY. An object is taken to be on the threshold or at the limit of visibility when it is seen just clearly enough so it can be identified. A light is taken to be on the threshold or at the limit of visibility when its intensity is just sufficient for the light to be located and seen steadily.

VISUAL RANGE. When an object or light is on the threshold, the distance between the object or light and the observer is called the visual range of that object or light.

VISIBILITY. In this article the term "visual range," when not referred to a particular object or light, is used to express what is usually called "visibility" by the meteorologist.

In order to obtain some idea of the functioning of the equipment, the transmissometer set may be conveniently divided into six separate components as shown in figure 4. A technical description of each of the main components is given below:

PROJECTOR. The projector consists of a sealed-reflector lamp operated at a constant intensity and an alignment system.

POWER SUPPLY. The projector power supply supplies power at a regulated voltage to the projector. Facilities are provided for making checks by turning the power off automatically at fixed intervals and off manually from the indicator.

RECEIVER. The receiver consists of a telescope to collect light from the projector (and at the same time exclude most of the light from the background) and a photoelectric receiver which provides an output signal in the form of pulses. The *pulse rate* is *proportional* to the *light incident* on the receiver lens and hence to the transmission.

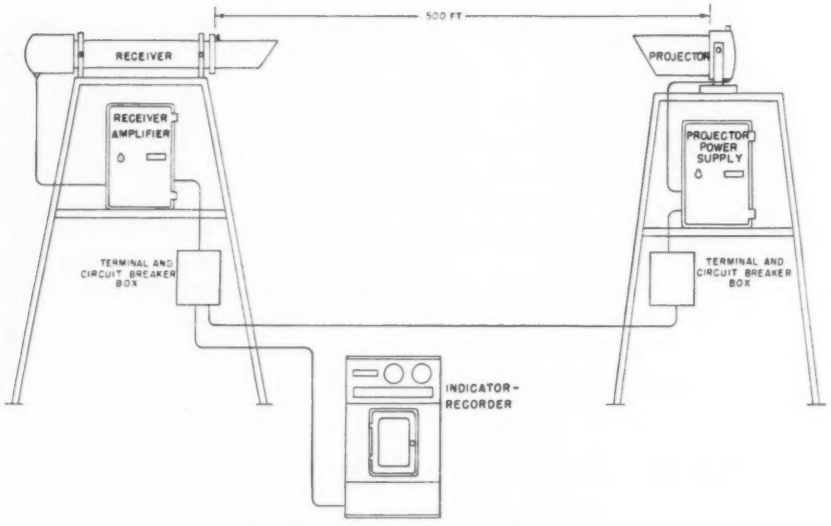


Fig. 4—How The Transmissometer Operates.

AMPLIFIER–POWER SUPPLY. This unit provides regulated voltage for the photoelectric receiver and amplifies the pulse signal of the receiver for transmission to the indicator. A metering unit is also provided to facilitate field adjustments.

INDICATOR. The indicator is essentially a frequency meter which converts the pulse signal to a direct current which is proportional to the pulse rate and hence to the transmission.

RECORDER. The recorder provides on a strip chart a continuous record of the output of the indicator.

The projector directs a light beam of constant intensity toward the receiver. The amount of light reaching the receiver varies with the density of the fog or haze in the path between these two instruments. A photoelectric detector in the receiver produces a signal in the form of pulses, the pulse rate being proportional to the light incident on the receiver. This pulse signal is amplified by the amplifier-power supply and transmitted to the indicator. Here the pulse signal is converted to a direct current proportional to the pulse rate. This current is continuously recorded. By proper adjustment of the set, the recorder reading is made to be 100 when the air in the path between the projector and receiver is perfectly clear. The set is then direct reading, giving the transmission of this path in per cent.

The observer can select two sensitivity ranges depending upon visibility conditions. On the *LOW* setting 4,000 pulses per minute produces a full-scale reading and a pulse rate of 800 pulses per minute produces a full-scale deflection on the *HIGH* setting. With the setting of the switch in the HIGH position, the sensitivity of the indicator unit is five times that with the switch in the LOW position. So for low visibilities the HIGH sensitivity position would normally be used.

The Air Weather Service plans to install within the next few years approximately 20 Transmissometer Sets AN/GMQ-10 at selected airfields within the continental United States and overseas. The projector and receiver will be located adjacent to the runway at the touchdown point. The projector and receiver will be installed on a 500-foot baseline. The indicator recorder will normally be located at the weather station.

Fig. 5—The transmissometer projector at MacArthur Field, Long Island, N. Y. NBS photo.

In summary, some of the advantages in the application of the Transmissometer Set AN/GMQ-10 are:

1. It supplements periodic visual observations by a continuous record.
2. It provides a record which can be analyzed to show variations and rate of change of conditions of visual range, particularly under low visibility conditions.
3. It replaces visual observations where trained observers cannot be efficiently utilized.
4. It provides a more accurate indication of visual range over a restricted area remote from an observer such as in touchdown areas.
5. It will give the pilot more satisfaction in knowing that the horizontal visibility data being relayed to him are measured objectively instead of subjectively.

Weatherwatch

Spring's Thermal Capriciousness

DAVID M. LUDLUM, *Editor*

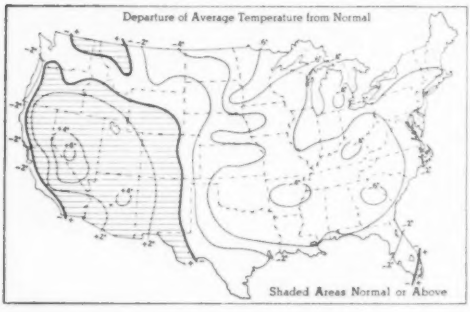
THE forces controlling the fluctuations in the air flow of the atmosphere over North America in May lived up to their 1954 form by once again reversing the circulation pattern from that which had dominated in the previous 30 days. This shift of the elements has occurred from month to month in each of the first six months of the current year. In the eastern two-thirds of the country, January, March, and May were generally cool months; a blocking high lay to the east of the continent and induced a relatively slow flow of the westerlies with a low index type of circulation. February and April, on the other hand, were outstandingly warm months in the central and eastern parts of the country with a strong flow of westerlies dominating the weather across the nation. Thus, the advocates of persistency in weather types and those addicted to making seasonal forecasts have had a difficult time with their specialities in 1954.

The main development in the pressure pattern of early May was the establishment of a blocking high in the northeastern corner of the continent and its subsequent extension southward into the western Atlantic Ocean. Pressure was much above normal over southern Greenland, Labrador, and the Maritime Provinces of Canada. The Icelandic low, accordingly, was rather weak. Further west a trough persisted over the Great Lakes area, a situation which encouraged the northward and southward movement of air masses during a greater part of the month. Again further to the west, upstream from the central trough, a ridge of high pressure took a position over the Plateau and Pacific states. Anticyclonic conditions there accounted for the persistence of very warm weather in the Southwest and Pacific states after the cool spell of the opening days of May. Above normal temperatures were general west of the Rockies except in a small strip in the extreme Northwest, and in Nevada plus departures for the month were as high as 6 degrees. The highest temperature reported was a reading of 115° at Cow Creek, California, in Death Valley on 18 May. The record for California in May is 121° established in 1910.

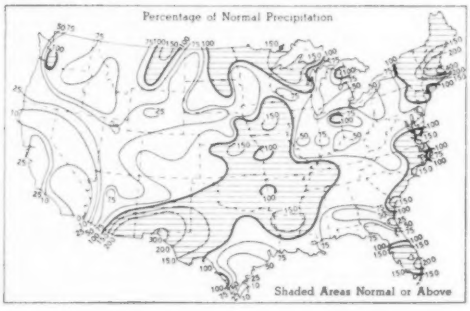
THE EARLY MAY COLD SPELL—The month opened with an active cyclone over the upper Great Lakes and a strong polar anticyclone to the northwest over the prairies of Canada. This general pattern tended to constantly reestablish itself for the first ten days of the month with the result that cold polar air of a very unstable quality poured southward with great persistency to set many new records for early May minima, for continued May cold, and for late season snowstorms. It had been very cold in central Canada during April, but the strong westerlies had prevented the southward movement of these air masses until the establishment of low index conditions about the first of May. In much of the Great Lakes-northern Plains area it was the coldest first decade of May on record. On the 1st a new state-wide low reading was set at Polebridge, Montana, with a mark of −5°.

Below-zero was also reported in Oregon—Fremont registered −2° for a new state low for May. The cold air masses spread over the entire eastern two-thirds of the country with the axis of flow from the upper Plains southeastward to Florida. Below-freezing occurred as far south as Georgia (Blairsville 30°) on the 6th. Widespread snows

MONTH OF MAY 1954



Departure of Mean Temperature from Normal in degrees Fahrenheit. USWB chart.



Percentage of Normal Precipitation. USWB chart.

accompanied the cold in the northern tier of states. The total fall for May at Bergland, Upper Michigan, was 21.9″ with a cover of 14″ reported on the 5th. Marquette, Michigan, had the deepest snowfall of May record with a 7.8″ covering. The snow area reached eastward to the mountains of Pennsylvania and the upland of New England where several inches fell on the 10th. A week later another surge of cold air brought snow all the way to the Tennessee-North Carolina mountains. May snowstorms in this area are not unheard of. A 14″ fall was recorded on 15–16 May 1843 and an 8″ storm on 19–20 May 1894. Snow in May also fell over Kentucky and Tennessee in the cold spring of 1854.

For the month as a whole it was the second coldest May since state records were coordinated in Missouri and also in the Southeastern states. In South Carolina, Georgia, and Missouri, May was colder than April, the first time this has occurred. The only comparable May in the Southeast was in the cold cycle of 1917. Many new late season minima were set in the Southland—Birmingham, Alabama, had a cool 40.4° reading on 21 May.

BOSTON'S DELUGE—May produced the greatest amount of rainfall ever registered in a single month at Boston. The 13.38″ measured at Logan Airport in Boston harbor was the greatest monthly amount since records were commenced in 1818. It was a month of dripping skies with rainfall being recorded on 18 days, a figure that has been exceeded only by 19 days in March 1877 and April 1912.

The highlight of the spring deluge came on the night of 15–16 May when 5.74″ fell in about 17 hours, a new May 24-hour mark and second only to the 6.04″ that fell on a July day in 1921. While Boston was being subjected to the month-long downpour, Provincetown, at the tip of Cape Cod only 50 miles to the southeast, had only 2.49″ for the entire month—such can be the varied rainfall pattern even in springtime coastal storms! The hourly totals of precipitation at Boston demonstrate the tremendous moisture-carrying ability of the atmosphere even at this northern locality. The figures are the hour ending at:

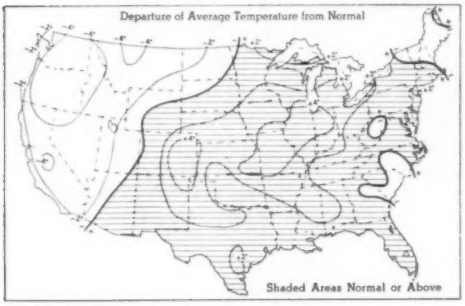
15 May—	2000	.03
	2100	.30
	2200	.23
	2300	.22
	2400	.49
16 May—	0100	.68
	0200	.52
	0300	.43
	0400	.92
	0500	.98
	0600	.50
	0700	.23
	0800	.04
	0900	.01
	1000	.05
	1100	.05
	1200	.05
	1300	.01
	1400	Trace
		5.74

The downpour caused local flooding throughout the Boston metropolitan area. The most serious situation developed at South Peabody where an ancient dam, which had withstood many previous heavy rains, gave way on the 16th and released a 13-foot wall of water in the center of the town. Flood water stood six feet deep in the business section of the town. Much inconvenience was caused in the suburbs by local flooding. The heavy rainfall, however, was confined to a small circle around Boston.

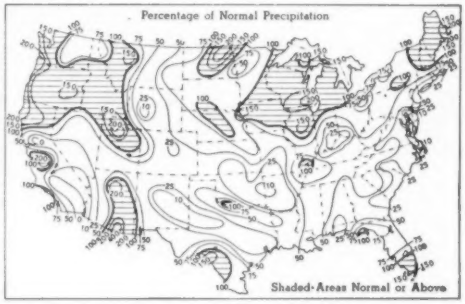
It was a very wet month generally throughout central and northern New England. A $3 million flood occurred along the Androscoggin River in eastern New Hampshire on the 8–9th, and on 29 May a cloudburst dropped 2.25″ in one hour at Union Village Dam in central Vermont.

JUNE—The month of June continued the swing of the thermal pendulum between warm and cold months that has marked the progress of 1954. May was cold in the area to the east of the Rockies, but warm to the west. June again reversed this situation with all but the immediate Atlantic seaboard experiencing very hot weather at the same

MONTH OF JUNE 1954



Departure of Mean Temperature from Normal in degrees Fahrenheit. USWB chart.



Percentage of Normal Precipitation. USWB chart.

time that the Plateau and Pacific states were decidedly cold.

These generalizations apply mainly to the last three weeks of June, for an important shift in the circulation took place at the end of the first week when a short period of active westerly control over the circulation in the mid-latitudes of the United States ended. Cyclonic activity diminished over the interior of the country, and the advance of cool polar air from either the Pacific or from Canada was slowed. It is interesting to note that three successive months—April, May, and June—all brought very cold weather during their first week to all central and eastern sections. In several southeastern localities new late season minima marks were set on more than one occasion during the spring of 1954.

THE BERMUDA HIGH—The controlling factor in the weather picture, as is usually the case in summertime, was the emergence of the so-called Bermuda High. It became the dominant force in chanelling air flow over the continent after 8 June when the westerly control diminished. As the month progressed, the high took a position over the central Gulf states and the lower Mississippi Valley. Here a strong individual cell developed that was connected with the main Bermuda-Azores high only by a narrow ridge or col of high pressure, and thus was permitted to develop a circulation system of its own over the United States. Like a giant pinwheel, the high cell swept vast streams of air of greatly varying qualities over the interior of the U. S. Since the center was well inland over the Gulf states, its southern edge lay over the Gulf of Mexico and set up an easterly stream of warm, moist air from that source region. Some of this moisture penetrated aloft to the central and northern Plains where shower activity was sporadic during the month, but in some cases very heavy. And during the third decade Gulf air moved northwestward at the surface over the Texas Coast and then up the Rio Grande Valley to New Mexico. The northward location of the high center at this time permitted the passage of an easterly wave around the southern border of the high, bringing it inland near the mouth of the Rio Grande River to supply the moisture for the cloudbursts and subsequent great flood over the plateau of south-central Texas.

Air flow around the western and northern borders of the high originated or was conditioned over the sun-baked deserts of the Southwest and northern Mexico. A great southwesterly current of dry tropical air set in about 10 June and grew hotter and hotter as the month progressed. Under the dominance of anticyclonic conditions, the sun drove the mercury to new high marks across a wide stretch of the country from the Rockies to the Atlantic. New June marks were set at Denver (101.8°) and at Memphis (104.2°); while at Macon, Georgia (106.3°) and Casper, Wyoming (100.6°), new all-time maxima for any month were set. St. Louis was near the epi-center of the heat wave as its mercury readings dramatically illustrate: on 10 June the mercury climbed to 94° and thereafter until the end of the month the airport station reported 90° or more with the single exception of the 16th when it was only 89°! The climax for June came on the 25–28th when readings were 100° or higher for four consecutive days. These figures, however, were only a sample of what was to come in July when even the marks set in 1934 and 1936 were toppled in the Missouri-Kansas area. The long-continued heat wave represented a distinct set back in the struggle to replenish soil moisture that had been depleted in the great drought of summer-fall-winter of 1953–54. Fortunately, spring rains had insured the wheat crop and had given corn an adequate start before the real torrid heat commenced.

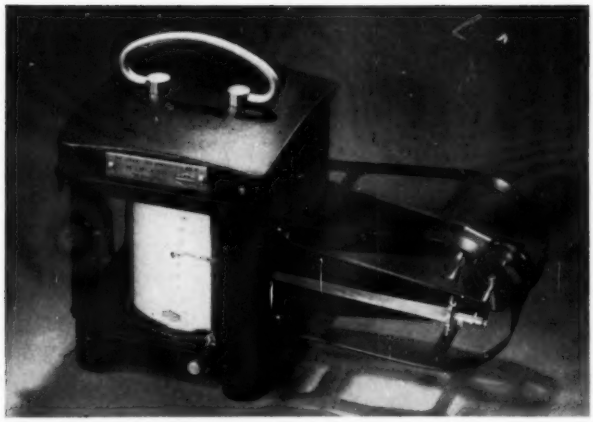
Oddly enough, despite the extent of the heat and returning drought in the Middle West and Southwest, the main weather news of the month resulted from too much rain. Both on the northern and southern edge of the heat wave cloudbursts caused damaging floods that were classified locally as the greatest in history when both the Des Moines River in Iowa and the Rio Grande River in south-central Texas exceeded all previous marks.

IOWA—Rainfall of the shower type had been frequent and heavy over parts of Iowa from early June on. Heavy showers fell on 20–21 June, some giving as much as 8.00″ in 24-hours. Streams in the northwestern and central parts of the state went over their banks. Flooding was especially severe on the Floyd, Racoon, and Des Moines rivers. The latter at Des Moines reached a peak of 30.2 feet on 24 June, nearly four feet above the previous record set on 26 June 1947 and about three feet above the flood marks of 31 May 1903, the two previous most serious floods. Dikes protected the city of Des Moines, but much damage was caused to rural communities and lowland crops upstream.

TEXAS—Not to be outdone by a sister state, Texas, which had just experienced the worst drought in its history, now produced the greatest flood on its greatest river. The Rio Grande from its junction with the Pecos above Del Rio down to the new Falcon Dam staged its worst rampage in history just a year after the same river had made headlines by running dry for most of the month of June 1953.

An easterly wave developed a tropical storm in the Gulf of Mexico which just reached hurricane force. On 25 June the center moved inland near Brownsville, Texas, and Matamoros, Mexico, attended by heavy, but not excessive rains. The circulation set up by the storm brought large quantities of moisture-laden air northwestward up the climbing Rio Grande Valley. Upon reaching the plateau areas northwest of Del Rio, the moisture was triggered over range lands. Up to 12 inches were reported, but measuring stations are few in the area. The Big Canyon, Pecos, and Devils rivers received the cloudbursts and poured their waters in the Rio Grande. The flood crested at Del Rio on Sunday, 27 June, at 40 feet, or 4.5 feet higher than the previous record set on 1 Sept. 1932. The flood reached Eagle Pass at a record height on Tuesday; and on the next day, 30 June, it crested at Laredo at 62.2 feet, which was 12½ feet above the September 1932 mark. The Falcon Dam below Laredo, recently dedicated by President Eisenhower, contained the flood and prevented damage further downstream. There were a number of lives lost, especially on the Mexican side, and property damage will run to several millions. About one-third of the city of Laredo was under water, and the International Bridge there was damaged by the loss of a span.

Thermograph



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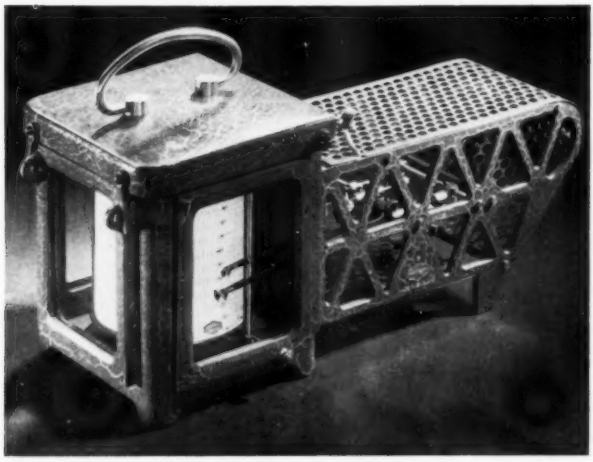

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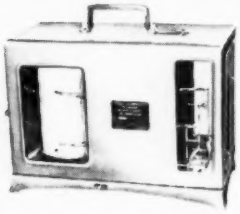

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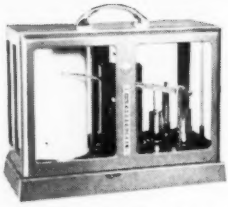

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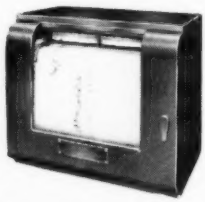

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